

THE WEATHER AND CIRCULATION OF MARCH 1964

Floods Followed by Extreme Cold

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1. HIGHLIGHTS

The most significant weather events of March in the United States were heavy rain in the Ohio Valley and southward during the first half of the month and an intense outbreak of Arctic air into the Plains States late in the month. Monthly rainfall records were broken for much of southwestern and central Ohio by mid-month. Resulting floods were near record severity in the southern half of Ohio. Floods also occurred in Kentucky, Indiana, Tennessee, Alabama, and Mississippi. Associated with the southward plunge of Arctic air in the latter part of the month was a late-season snowstorm that dropped up to 9 in. of snow in the Chicago area on March 29. This storm moved eastward, leaving snow over the Great Lakes Region, the upper Ohio Valley, parts of Pennsylvania, and nearby areas. Dulles Airport, near Washington, D.C., received 5 in. on March 30.

Although the Arctic air of the final week warmed considerably as it moved southeastward, the peach belt of the Southeast still suffered extensive damage from freezing temperatures. Damage was very heavy in the Carolinas, "with North Carolina's crop virtually a complete loss" [1]. Other States in which the peach crop was damaged by the freeze were Georgia, Tennessee, Arkansas, and Mississippi.

Along, and immediately in advance of, the leading edge of the Arctic air, extensive and severe thunderstorm and tornado activity occurred, especially in the midsection of the country on March 25. Garwood and Centerville, Mo., and Addison, Ala., were hit by tornadoes as the cold air approached. A thunderstorm at Topeka, Kans., produced a combination of sleet, freezing rain, and hail, while at Kansas City, Mo., hail as large as golf balls fell. Tornadoes were also reported with earlier weather systems in Mississippi, Tennessee, and Alabama.

2. MEAN CIRCULATION

Most of the major features of the mean 700-mb. circulation (fig. 1) were displaced from their normal positions during March. In many areas of the Northern Hemisphere this represented a large change from the previous month when "abnormally strong ridges near their normal positions" [2] were distributed around the hemisphere.

The ridge ordinarily over western North America during March was offshore over the eastern Pacific, while the usually deep broad trough near the east coast of the United States was replaced by two troughs. One of these extended southeastward from the Davis Strait into the central Atlantic, and the second trough extended southwestward from eastern Canada to northern Mexico, giving below normal 700-mb. heights (fig. 2) to most of North America. A weak positive height anomaly over the western Atlantic reflected the slight mean upper-level ridge just off the east coast. The Baffin Island Low was near its normal location but was more than 400 ft. deeper than expected for March.

A strong blocking High was centered over Scandinavia, accompanied by a 480-ft. positive height anomaly (fig. 2). This High developed early in the month and was the most persistent system of the Northern Hemisphere circulation during March. The negative height anomalies of the mid-tropospheric circulation over much of Asia were related to the deep trough from the polar basin to Lake Baikal, where a ridge is normally situated in March. Heights of the 700-mb. level over the Mediterranean Sea were close to normal. Over extreme eastern Siberia the connection from the polar Low to the Kamchatka Low was weaker than normal, and the trough southward from Kamchatka was displaced eastward giving small positive 700-mb. anomalies over much of the western Pacific.

The Pacific circulation was quite unusual, for the normal Pacific flow of the mid-troposphere in March shows maximum cyclonic curvature in western and eastern extremities with nearly zonal flow in between. However, this March 700-mb. heights were above normal in the extremities and below normal near the central Pacific where cyclonic activity was at a maximum.

The jet axes at 700 mb. (fig. 3) were close to their normal positions over most of the oceans, especially the Pacific. But, over the continents and the eastern Atlantic Ocean, these axes were noticeably removed from their normal locations. In the United States the principal axis of maximum westerlies, instead of being across the central portion of the country as shown by the dashed line in figure 3, was displaced to the south.

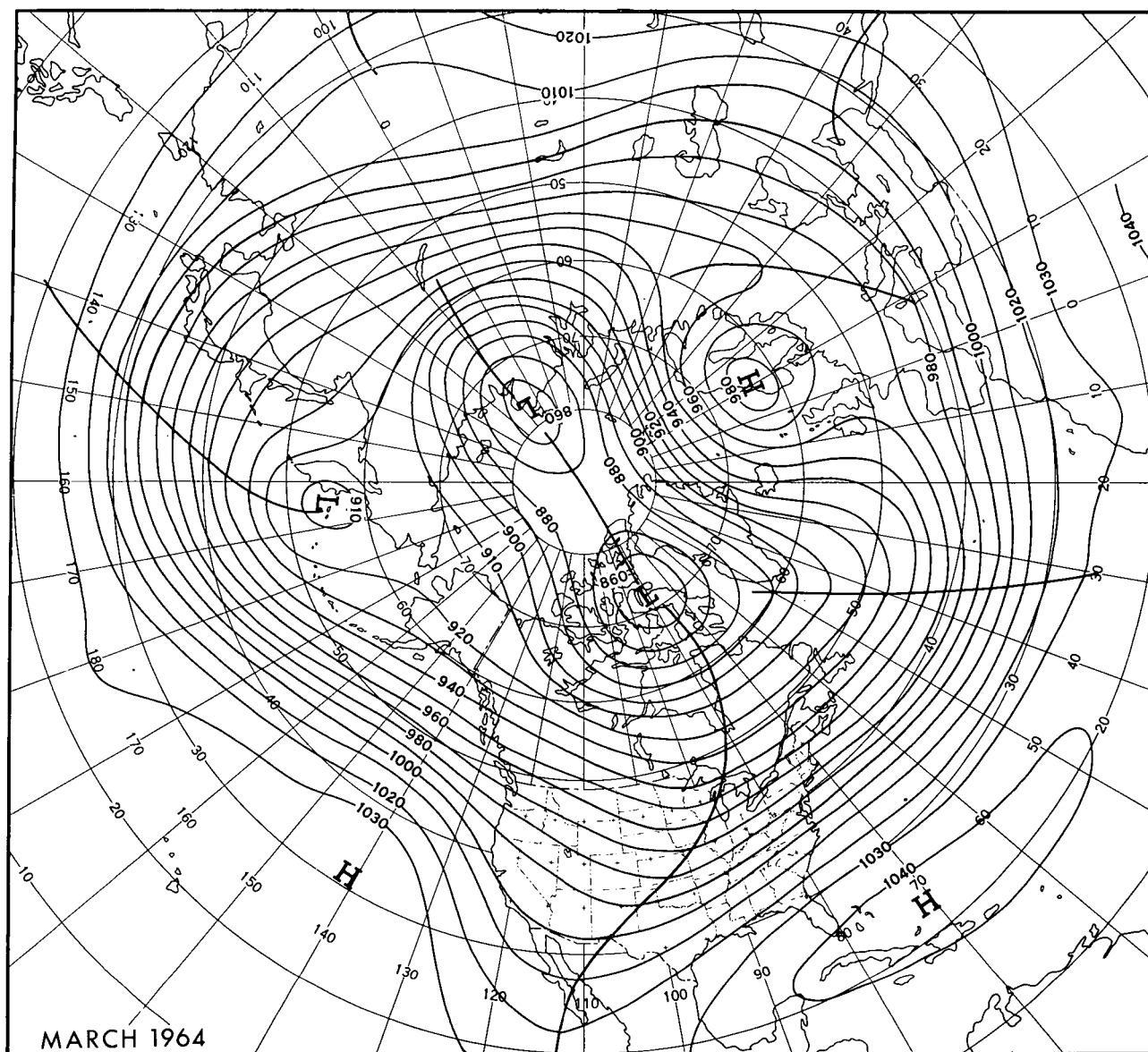
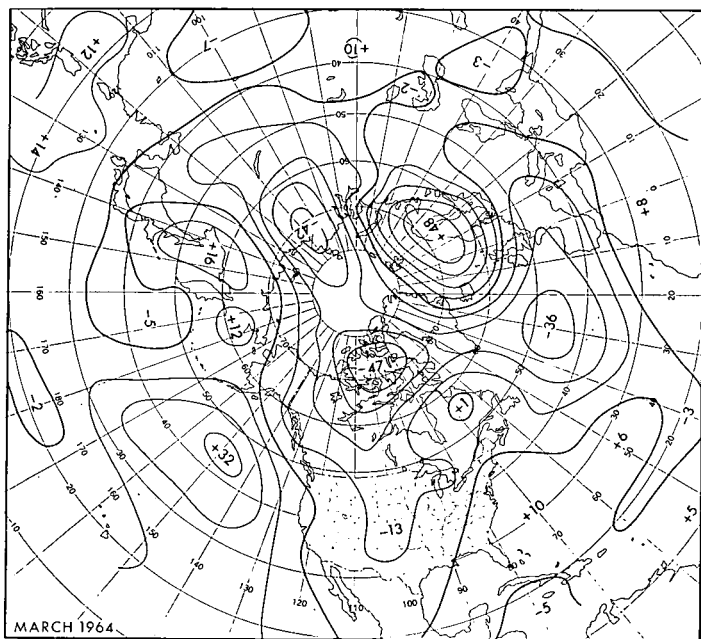


FIGURE 1.—Mean 700-mb. contours (in tens of feet) for March 1964.



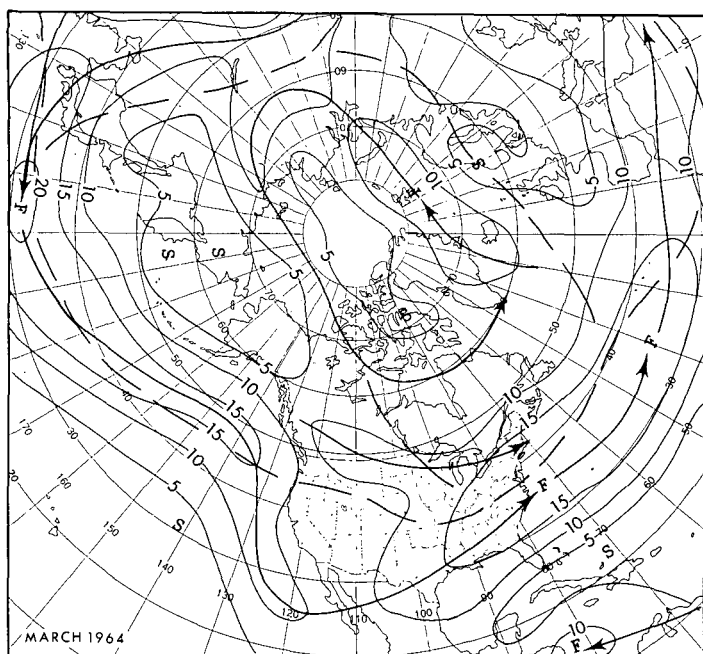


FIGURE 3.—Mean 700-mb. isotachs in meters per second for March 1964. The heavy solid arrows indicate observed axes of maximum wind speed, while dashed lines show the normal axes for March.

3. AVERAGE MONTHLY WEATHER TEMPERATURE

Temperatures were above normal in most areas east of the long-wave trough through the central United States (figs. 1 and 4). However, none of the Eastern States experienced large monthly temperature departures, mainly, because the early-month warm period in the East changed to a cooling trend during the latter half of the month. Greatest departures were observed in southern Florida where values were slightly more than 4°F. above normal.

To the west of the long-wave trough, temperatures were below normal except in a very small part of south-central Washington and north-central Oregon. The degree of coldness was greater in the West than was the warmth of the East for two major reasons. First, the cold regimes were more persistent; second, some of the outbreaks of cold air were quite intense. The largest average below-normal temperature was 8°F. in a small area of the central Plateau and Rocky Mountain States, where Pocatello, Idaho reported the coldest March since 1917. This extremely low monthly mean temperature is best explained by the presence of anomalous snow cover during the entire month. Many areas in the United States had unusual snow cover in March, but only in this section did the snow anomaly persist all month. This instance supports long-held beliefs by Namias [3] and others as to effects of the underlying surface conditions on the temperature.

The relation of the temperature regime to the upper-

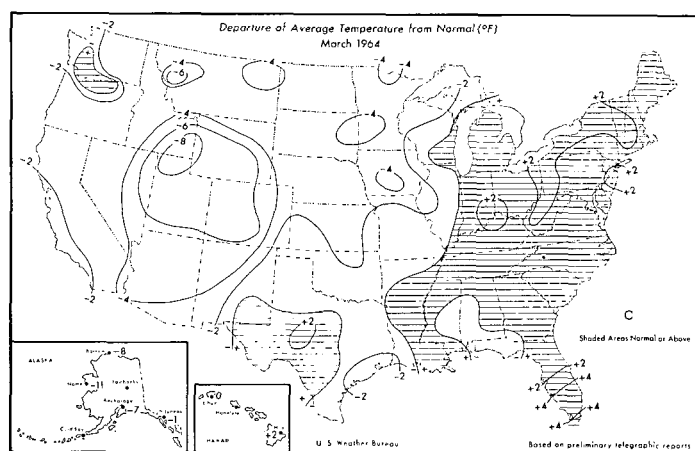


FIGURE 4.—Departure of the average surface temperature from normal for March 1964 (from [1]).

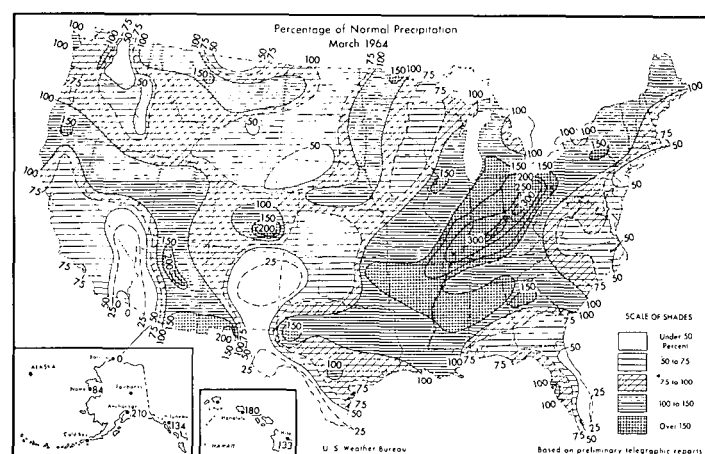


FIGURE 5.—Percentage of normal precipitation for March 1964 (from [1]).

level circulation this month was straightforward and simple. Warm air was observed to the east of the long-wave trough under southerly anomalous flow; but since 700-mb. heights in this region were near normal (fig. 2), the departures from the normal temperature were small. To the west of the trough northwesterly flow, below-normal 700-mb. heights, and widespread and persistent late-season snowfalls amply account for the below-normal temperatures. Also the anomalous flow (fig. 2) was parallel to the Rocky Mountain range, thus preventing any foehn condition in the average. There was one week in which foehn warming was pronounced, but later more northerly winds overshadowed both circulation and surface temperature effects of this week.

Further evidence of the simplicity of the circulation and temperature regime this month is supplied by Klein's [4] equations, which also specified a simple warm-east and cold-west temperature pattern for the United States. The boundary line between the above normal and the below normal temperatures was placed by Klein's method

somewhat farther west in Northern States than was observed. The more extreme observed anomaly in this area can be accounted for by the widespread snow cover that persisted across the North much later than normal.

PRECIPITATION

Southerly surface winds on the western side of the Bermuda High intruding into the Southeast brought a flow of warm moist air over most of the eastern United States, especially during the first half of the month. Vertical motions associated with frequent storminess east of the long-wave trough in the Midwest then precipitated copious quantities of this moisture in the eastern half of the country (fig. 5). A maximum of 14 in. was centered over the Ohio Valley with a secondary maximum of 10 in. in Mississippi and Alabama. As shown in figure 5, this represented more than 300 percent of the normal March rainfall for parts of the Ohio Valley.

Cyclonic activity even in the rear portion of the deep trough was sufficient to give some above-normal precipitation in the West, especially in Montana. Extensive above-normal precipitation also fell in a fairly wide strip through southern Oregon, northern California, Nevada, Utah, Arizona, and southwestern New Mexico. As in the Ohio Valley, precipitation in the Southwest was in sharp contrast with earlier conditions. O'Connor [2] referred to "one of the driest and sunniest Februaries ever recorded west of the Continental Divide." The same band of precipitation included the El Paso area of Texas, which, along with parts of Arizona and New Mexico, reported more than twice normal rainfall. El Paso had received no measurable rainfall for the three preceding months.

The relatively dry areas this month were quite small and isolated, there being five such areas scattered throughout the western half of the country (fig. 5). Only the Yuma, Ariz. area reported no measureable rainfall this month.

4. INTRA-MONTHLY VARIATIONS IN WEATHER AND CIRCULATION

MARCH 1-15

A very intense upper-level Low was centered north of Hudson Bay in the first half-month mean circulation (fig. 6A) with a deep long-wave trough trailing southward to northern Mexico. Comparison of figure 6A

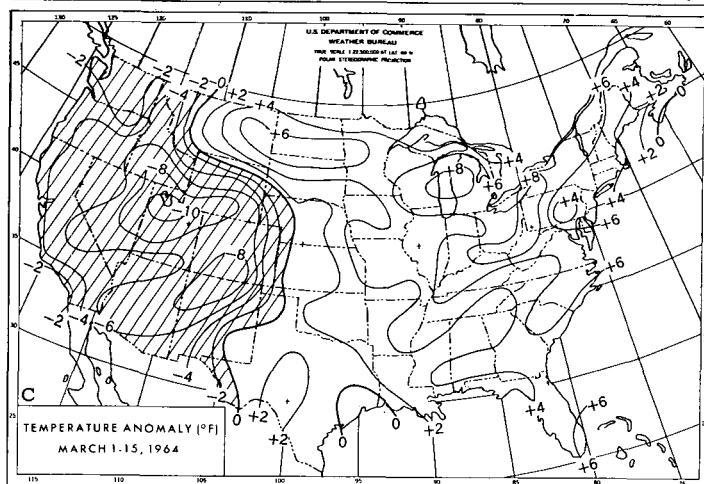
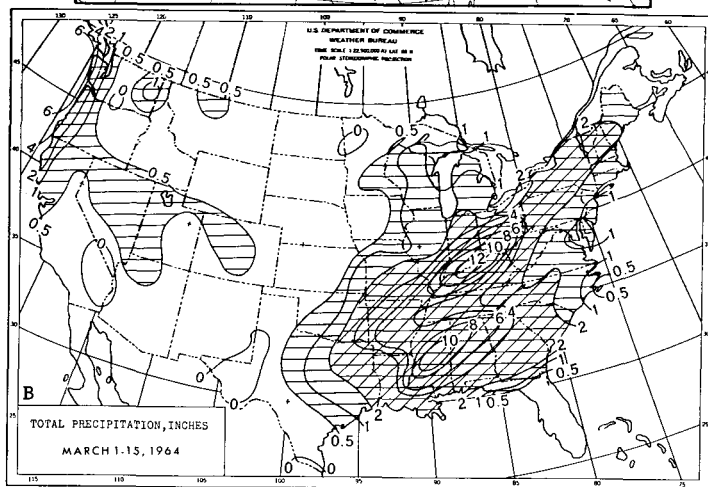
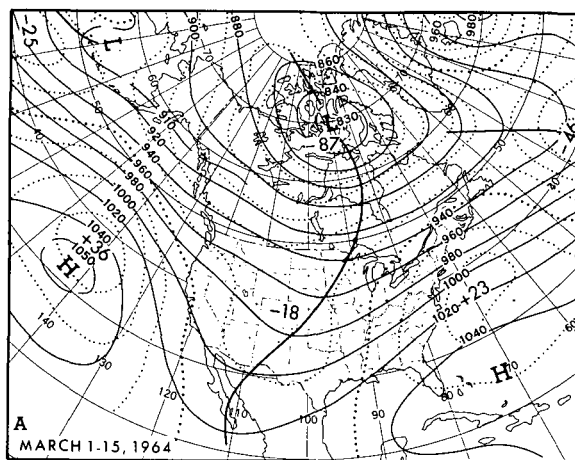


FIGURE 6.—(A) 700-mb. height and departure from normal (both in tens of feet); (B) total precipitation (less than 0.5 in. unshaded, 0.5 to 2 in. hatched, more than 2 in. crosshatched); (C) surface temperature departure from normal (below normal hatched); all for March 1-15, 1964.

TABLE 1.—New precipitation records established in March 1964

Station	March total (in.)	24-hour	
		Total (in.)	Date
Cairo, Ill.	12.67	6.58	8-9
Evansville, Ind.	12.84	5.63	8-9
Louisville, Ky.	14.91	6.97	9
Cincinnati, Ohio	11.49		
Columbus, Ohio	9.49	3.40	9

with figure 1 shows that the first half-month circulation over North America was strong enough to mask variations that occurred in the last half of the month. In the first 10 days of the month, not only was the trough in the Midwest very deep, but also the ridge off the east coast

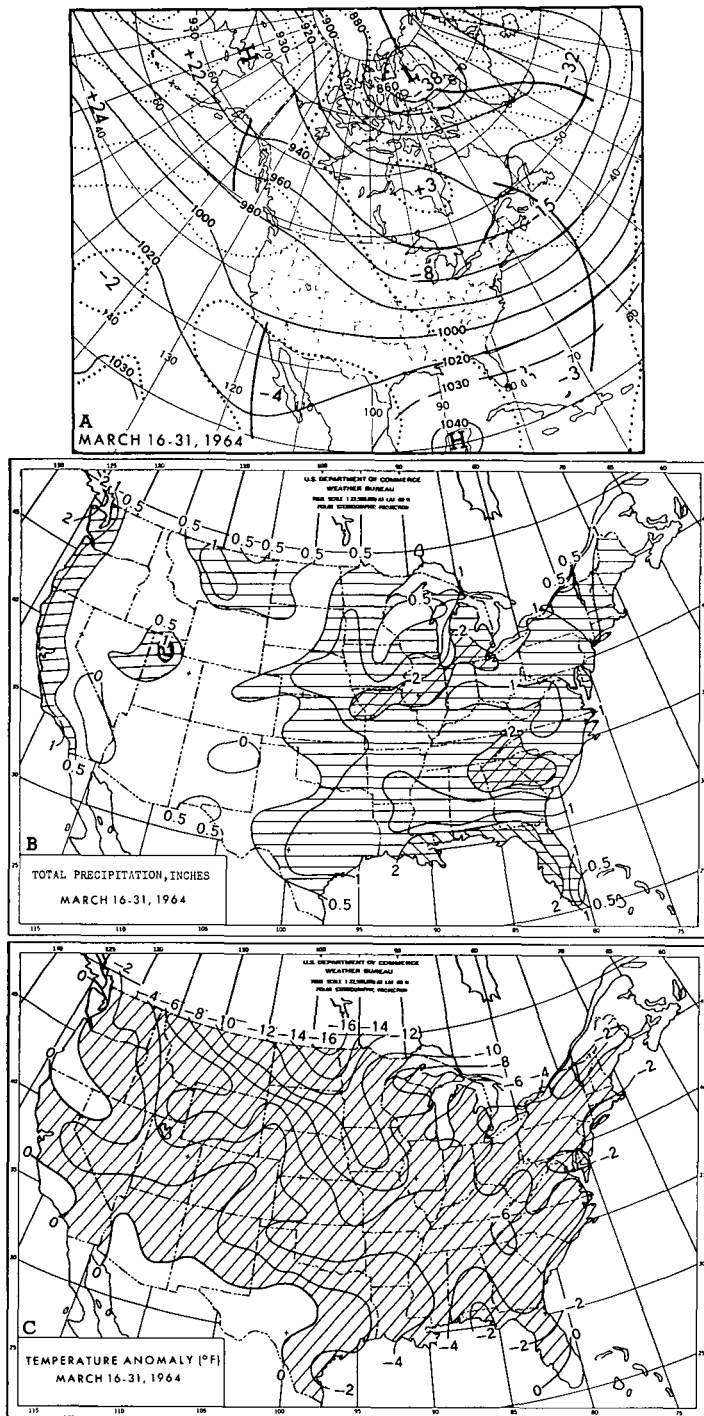


FIGURE 7—(A) 700-mb. height and departure from normal (both in tens of feet); (B) total precipitation (less than 0.5 in. unshaded, 0.5 to 2 in. hatched, more than 2 in. crosshatched); (C) surface temperature departure from normal (below normal hatched); all for March 16-31, 1964.

was quite strong. The resulting southerly flow brought warm and quite moist air from the Gulf of Mexico up the Mississippi Valley.

Frequent storm activity released large quantities of precipitation over much of the eastern half of the nation.

Heaviest rainfall was in the Ohio Valley (fig. 6B) where many stations, as shown in table 1, exceeded or equaled previous rainfall records for March. One storm of March 8-9 gave 24-hr. amounts of rain which made new 24-hr. records and also accounted for almost half of the very large monthly totals.

Precipitation was generally light over the Plains States west of the mean trough, but some storms did give fairly good precipitation amounts while moving through the Rocky Mountains and the Great Basin area into the central part of the country. More than an inch was recorded at Salt Lake City and 0.97 in. was measured at Pueblo, Colo. Much of this precipitation was snow, with extensive snowfall even reaching into southern Arizona and southern New Mexico early in March. Tucson reported 5 in. on the 3d and Roswell, N. Mex., 1 in. on the 4th. Stronger than normal upper-level westerly winds on the Northwest Coast gave heavy rain (up to 7 in.) to coastal areas of Washington and Oregon during the first half of March.

Temperatures were well above normal over much of eastern United States during the first 15 days of March (fig. 6C), as would be expected with the anomalous 700-mb. flow shown in figure 6A. There was enough foehn to cause temperatures in the Northern Plains to be above normal also; even though this area was on the western side of the upper-level trough and had below normal 700-mb. heights. The region west of the Continental Divide had below-normal temperatures because of the strong ridge in the eastern Pacific, below-normal 700-mb. heights, and northerly anomalous flow west of the Rockies.

MARCH 16-31

During the latter half of March the major long-wave trough in the vicinity of North America was off the east coast of the United States (fig. 7A), causing the most intensive cyclonic activity to be over the ocean. Still, the maximum curvature area from the Great Lakes into the Southern Plains reflected six fairly active surface depressions that moved through the eastern half of the country after the middle of March. Figure 7B shows three sections east of the Continental Divide with more than 2 in. of precipitation. One area included the southern Appalachians; another extended from southern Michigan across central Illinois through northern Missouri; and the third section extended in a narrow band along the Gulf Coast from Louisiana to Florida.

The low-latitude trough west of Baja California (fig. 7A) resulted in rain along the California coast. However, this late March precipitation, which ranged from 0.7 in. at San Diego to about 2 in. at Point Arguello, left most of the central region and interior California (except the extreme north) with below normal precipitation for March (fig. 5). The rains at Point Arguello did give amounts 0.5 in. above normal for that immediate area. The anomalous easterly flow aloft in the North-

west in the last half of March (fig. 7A) produced relatively light rainfall along the coasts of Washington and Oregon.

Precipitation in the Rocky Mountains, Great Basin, and adjacent areas was the result of several migratory storms with no one system giving more than light to moderate amounts in general. One storm brought a 12-in. snowfall to Salt Lake City, Utah; Flagstaff, Ariz., reported 21 in. of snow depth on the 25th, most of which had fallen in one storm. Yuma, Ariz., Tonopah, Nev., and Albuquerque, N. Mex., all reported no measureable precipitation in the last half of March.

With the decrease in intensity of the ridge in the eastern Pacific and its progression into western Canada (compare figs. 7A and 6A), the relative cold west of the Continental Divide moderated. In fact, temperatures were slightly above normal in coastal Washington and Oregon, northwestern Nevada, and two localities in California (fig. 7C). This slight warmth was in keeping with an increase in 700-mb. heights and weak easterly anomalous flow aloft along the west coast (fig. 7A).

The intense and extensive negative temperature anomaly centered in the Northern Plains and extending to the east coast was caused by continental polar and Arctic air masses. These cold air masses were deployed southward by the strong ridge in the polar westerlies north of Alaska and the ridge in mid-latitude westerlies over western Canada. An outbreak of extremely cold Arctic air occurred in the final week of March, bringing temperatures as low as -20°F . at Williston, N. Dak., and below zero temperatures to several neighboring States. The very

TABLE 2.—Record low temperatures for March established in 1964

Station	Temperature (°F.)	Date	Type of record	Length of record (yr.)
Daytona Beach, Fla.....	39	31	for date.....	20
Jacksonville, Fla.....	32	31	so late in season.....	22
Athens, Ga.....	27	31	for date.....	20
St. Cloud, Minn.....	0	28	.....do.....	24
Vicksburg, Miss.....	31	30	.....do.....	26
Asheville, N.C.....	15	30	so late in season.....	33
Greensboro, N.C.....	20	31	.....do.....	34
Wilmington, N.C.....	25	31	.....do.....	93
Chattanooga, Tenn.....	24	30	.....do.....	24
Memphis, Tenn.....	23	30	.....do.....	22
Nashville, Tenn.....	21	30	for date.....	24
Richmond, Va.....	17	31	so late in season.....	34

cold air reached the Southeast in the last days of the month, setting many new records of extreme minima so late in the season. Some of the stations reporting record low temperatures are shown in table 2.

REFERENCES

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3. J. Namias, "Influence of Abnormal Heat Sources on Atmospheric Behavior," *Proceedings of the International Symposium on Numerical Weather Prediction, Tokyo, Nov. 7-13, 1960*, Meteorological Society of Japan, Mar. 1962, pp. 615-627.
4. W. H. Klein, "Specification of Monthly Mean Surface Temperatures from 700-mb. Heights," *Journal of Applied Meteorology*, vol. 1, No. 2, June 1962, pp. 154-156.